Influence of FeTiO$_3$ Addition on TiO$_2$ Coating Formation Characteristics in Plasma Spray

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Abstract

To improve the visible light responsivity of TiO$_2$, FeTiO$_3$ with band gap of 2.85 eV was added into TiO$_2$ powder with band gap of 3.2 eV in this study. The microstructure and phase compositions of plasma sprayed TiO$_2$, TiO$_2$-30%FeTiO$_3$, TiO$_2$-50%FeTiO$_3$ and FeTiO$_3$ coatings were investigated. The FeTiO$_3$ coating plasma sprayed under the arc current of 400 A consisted of rutile TiO$_2$, FeTiO$_3$, Fe$_2$TiO$_5$, and thermally metastable Fe$_2$Ti$_3$O$_9$ and $\gamma$-Fe$_2$O$_3$, while TiO$_2$-30%FeTiO$_3$ coating contained anatase TiO$_2$, rutile TiO$_2$ and FeTiO$_3$ only. The relative deposition rate of TiO$_2$-30%FeTiO$_3$ powder under the arc current of 400 A was approximated to be 4 $\mu$m/pass.

Keywords: TiO$_2$, plasma spray, photocatalyst, FeTiO$_3$

1. Introduction

To solve the environmental problems related to the hazardous wastes, contaminated groundwater and toxic air contaminants, extensive research is underway to develop commercial photocatalysts, which include TiO$_2$, CdS, WO$_3$, ZnO, and SrTiO$_3$ etc. Among all the oxide semiconductors that have been reported, titanium dioxide is an excellent photocatalyst due to its optical and electronic properties, chemical stability, non-toxicity and low cost.

However, it has been also realized that the band gap of anatase TiO$_2$ (about 3.2 eV) means that the electron can only be excited from the valence to the conduction band by the high power light irradiation with a wavelength less than 387 nm. This limits the application of sunlight as an energy source for the photocatalysis. Recently, visible light responsive photocatalysts are studied intensively.

The band gap of bulk FeTiO$_3$ is 2.85 eV, which means it can absorb visible light. FeTiO$_3$ is an incongruent melting material with the melting point of approximately 1683 K. To elucidate the influence of FeTiO$_3$ on the photocatalytic activity of plasma sprayed TiO$_2$-FeTiO$_3$ coatings, TiO$_2$, FeTiO$_3$ and TiO$_2$-FeTiO$_3$ powders were designed in this study. The influence of FeTiO$_3$ on TiO$_2$ coating formation characteristics in plasma spray were discussed in detail. And the photocatalytic activity of deposited coatings will be given in oral presentation.

2. Materials and Experimental Procedure

2.1 Feedstock Powders and Substrate

FeTiO$_3$ particles with average size of 1.4 $\mu$m were agglomerated to FeTiO$_3$ feedstock powder with average size of 32.5 $\mu$m. To manufacture TiO$_2$-30%FeTiO$_3$ and TiO$_2$-50%FeTiO$_3$ feedstock powders, TiO$_2$ particle with average size of 0.2 $\mu$m was mechanically and uniformly mixed with 1.4 $\mu$m FeTiO$_3$ particles with corresponding weight ratio. The average size of TiO$_2$, TiO$_2$-30%FeTiO$_3$ and TiO$_2$-50%FeTiO$_3$ feedstock powders was 33.7 $\mu$m, 30.4 $\mu$m and 28.9 $\mu$m, respectively. The substrate was stainless steel (JIS SUS304).

2.2 Plasma Spray Equipment and Characterization

The thermal spray equipment was a plasma spray system (Plasmadyne-Mach1, Miller Thermal, USA). Argon was applied as primary gas, and helium was applied as secondary gas. The thermal spraying parameters are given in Table 1.

The phase compositions and microstructure were examined by XRD and SEM. To evaluate the fabrication characteristics of the feedstock powder at various plasma spraying conditions, the powder deposition rate was defined as RDRP. The definition of RDRP was given in previous report in detail.

<table>
<thead>
<tr>
<th>Table 1 Plasma spraying parameters.</th>
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<tr>
<td>Argon gas pressure (MPa) /flow (slpm)</td>
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<tr>
<td>Helium gas pressure (MPa) /flow (slpm)</td>
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<tr>
<td>Arc current (A)</td>
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<td>Arc voltage (V)</td>
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<td>Spraying distance (mm)</td>
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3. Results and Discussion

3.1 Typical Microstructure of FeTiO$_3$ and TiO$_2$-FeTiO$_3$ Coatings

The coating became denser with the increasing of
arc current for the higher plasma power according to the cross section of TiO₂-30%FeTiO₃ sprayed coatings. As clearly shown in Fig.1, many primary particles with average size of about 200 nm remained in the coating sprayed under the arc current of 400 A for the low energy transferred from plasma jet. The Relative Deposition Rate of TiO₂-30%FeTiO₃ Powder (RDRP), which was approximated to be 4 μm/pass, did not differ significantly from that of TiO₂ powder as shown in Fig. 2. With the increase of arc current to 600 A or 800 A, the relative deposition rate of TiO₂-30%FeTiO₃ powder increased obviously.

![Fig.1. Surface morphologies of TiO₂-30%FeTiO₃ coating sprayed under the arc current of 400 A (a) low magnification, (b) high magnification.](image)

Fig.2. Relative deposition rate of TiO₂, TiO₂-30%FeTiO₃, TiO₂-50%FeTiO₃ and FeTiO₃ powder (RDRP) under the arc current of 400A, 600A and 800A.

3.2 Compositions of FeTiO₃ and TiO₂-FeTiO₃ Coatings

According to the x-ray diffraction patterns of plasma sprayed FeTiO₃ coating under the arc current of 400 A, the FeTiO₃ coating consisted of rutile TiO₂, Fe₂TiO₅, Fe₂Ti₃O₉, and γ-Fe₂O₃ (maghemite). Y. Chen⁷) reported that the thermal oxidation process of Fe₂Ti₃O₉ and γ-Fe₂O₃ in FeTiO₃ feedstock powder, Fe₂TiO₅ and Fe₂Ti₃O₉ phases appeared under the low arc current of 400 A for the large content of low melting point FeTiO₃ in the powder.

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4. Conclusions

To improve the visible light responsivity of TiO₂, FeTiO₃ with band gap of 2.85 eV was added into TiO₂ powder to fabricate high photocatalytic coating by plasma spraying technique. The phase compositions and microstructure of plasma sprayed FeTiO₃, TiO₂-30%FeTiO₃ and TiO₂-50%FeTiO₃ coatings were investigated. The FeTiO₃ coating plasma sprayed under the arc current of 400 A consisted of rutile TiO₂, Fe₂TiO₅, Fe₂Ti₃O₉, and thermally metastable Fe₂TiO₅ and γ-Fe₂O₃, while TiO₂-30%FeTiO₃ coating sprayed under the arc current of 400 A contained anatase TiO₂, rutile TiO₂ and FeTiO₃ only. The relative deposition rate of TiO₂-30%FeTiO₃ powder under the arc current of 400 A was approximated to be 4 μm/pass.

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References